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## PROJECT 42 - AN HISTORICAL RECORD

### Introduction

The purpose of this record is to summarize the events that took place in the development and testing of the Model 504 radar jamming equipment and to present any significant conclusions or opinions regarding the performance of the equipment and the nature of the job which the equipment is expected to do.

### Design and Construction

In mid-July, 1958, design of the Model 504 equipment was begun. The primary function of the Model 504 is to provide airborne angle deception of X-band conical scan tracking radars through the use of the inverse gain technique. Provision for performing velocity gate pull-off of X-band C-W doppler radars was also included. The equipment uses two cascaded TWT's with a maximum output power of one watt. Inverse gain is performed by applying modulation of the proper phase and frequency to the grid of the output TWT while velocity gate pull-off is performed by serradyne modulation of the helix of the output TWT. The output TWT is maintained in a cut-off condition until the Model 504 is illuminated continuously by either a pulse or C-W signal. The type of signal received determines the mode of operation of the equipment.

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Construction and bench debugging of the Model 504 were completed in October, 1958, and the equipment was transported to Edwards Air Force Base for installation in the aircraft and airborne testing.

## Installation and Passive Testing

Installation of the Model 504 in the airplane was accomplished in late October and a flight was made at 20,000 ft. to check for any mechanical problems and to check for voltage breakdown. The equipment was operated for about one-half hour at altitude with power on but no illumination. No trouble was encountered.

In order to check the receiving capabilities of the Model 504, two flights were made against a Nike tracking radar at Indian Springs. On the first flight a malfunction occurred in the Model 504 which caused the "Jammer On" light to remain on at all times regardless of illumination. The trouble was traced to noise pickup in the cabling to the Model 504 and was eliminated. On the second flight the Nike radar was used to illuminate the Model 504 and energize the Pulse Radar detection circuit. The Model 504 then operated as a noise modulated repeater and the Nike was able to maintain lock-on out to a range of 60 miles.

A flight was made against an F104 at Edwards Air Force Base to provide a further check on the receiving capabilities of the Model 504. The 504 operated as expected and no attempt was made to determine if any angle deception of the F104 had

occurred.

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**SECRET**Active Testing - Part I

Early in November active testing at Point Mugu was begun with an instrumented F3H with Hughes AN/APG-51B radar as the chase plane. The GCI facilities at Mugu were used to line the two airplanes up on a collision course and to monitor the runs giving continuous range and bearing information. The tests were run at a fixed altitude of 20,000 ft.

Several flights were made during part one of the Mugu testing. However, only the results of the first flight were usable because of erratic radar performance on the following flights.

On the first flight when the F3H radar locked on, the Model 504 came on. The aim dot on the radar presentation would then trace a circular path instead of staying in one position. When the pilot attempted to follow the aim dot by averaging its excursions, the F3H was led downward in elevation, reaching a maximum offset of several thousand feet. Lock on would occur at about 12 miles. At a range of about 6 miles the effectiveness of the Model 504 began to decrease, probably due to saturation of the output TWT, so that at the normal F3H firing range of 2 - 3 miles, the error involved was small and successful firings could easily have been made, as well as visual contacts.

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Inverse Gain Study Program

Results of the first active tests were rather disappointing in that the radar was able to maintain automatic track at all times and very little error occurred at short range.

In order to gain a better understanding of the inverse gain process, a study program was initiated in mid-November. It was felt that existing analyses were oversimplified and did not present an accurate enough picture of the inverse gain process.

The inverse gain study made by Granger Associates is contained in a separate report and only the conclusions will be presented here.

The analyses used a typical fire control radar antenna pattern to determine signal modulation patterns and resulted in three significant conclusions:

- 1) Quite large  $J/S$  ratios are required (in the order of 26 db) to produce a target offset which reaches the first antenna null.
- 2) The jammer return must be accurately controlled in width and phase to obtain the minimum required  $J/S$  ratio.
- 3) Once the target offset has been pushed to the first antenna null, it is likely that the radar will lose lock completely due to the additional offset then available and the consequent reduction in signal power available to the radar receiver.

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**SECRET**Modification of Model 504

In view of the conclusions reached in the study program it was felt that certain changes could be made in the Model 504 equipment to improve its performance and to increase the probability of "Lock Break."

In order to increase the Jam to Signal ratio presented by the Model 504 and the target airplane, the electronic RF gain was increased by 10 db to the maximum allowable RF gain of 55 db. Larger RF gain would cause instability because of insufficient isolation between the input and output horns. The actual magnitude of the  $J/S$  ratio is not known, since no reliable data on radar cross-section of the airplane is available. It is believed that the radar cross-section is between 0.5 and 5 square meters which would give a  $J/S$  ratio between 40 and 30 db.

In order to maintain the width of the Model 504 return ~~to~~ <sup>at</sup> about  $160^\circ$  regardless of input modulation waveform, a duty cycle regulating circuit was incorporated in the inverse gain limiting amplifier.

Rather than install sufficient circuitry to maintain the proper phase in the Model 504 return over the full range of conical scan frequencies, it was felt that valid information could be obtained by installing a simple lead network to optimize the phase at the F3H radar conical scan frequency. Any future equipment would contain the necessary broadbanding circuits.

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**SECRET**Active Testing - Part 2

Early in December 1958 active tests were resumed at Point Mugu using the modified Model 504 against the F3H. Two flights were made on December 9 with a total of 10 straight-in, active runs and 2 calibration runs. In general, on the active runs the radar repeatedly lost lock into a range of about 5 miles. At closer ranges the effectiveness of the Model 504 decreased, probably due to saturation of the output, so that in most instances the F3H was able to make successful firings at 2 - 3 miles.

The F3H pilot commented that the radar lost lock when a bright spot appeared on his Range trace and moved into the range gate. It is believed that the bright spot was caused by ground return picked up because of antenna offset caused by the Model 504.

In order to improve the performance of the Model 504 at close ranges, it was felt that the AGC system should be modified. The original AGC system operated on the average input signal so that at large antenna offsets, when the modulation of the input signal was very large, the gain of the RF channel was reduced more than necessary. Since the Model 504 is only on during the time that the input signal is weakest, the AGC system was modified to operate on the weakest part of the input signal.

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The first attempt at making this modification involved moving the video detector from the output of the first TWT to the input. This resulted in a lower signal-to-noise ratio and a reduction in sensitivity of about 10 db. A flight test of this modification gave poor results since the Model 504 did not come on until the range was less than 6 miles.

The video detector was changed back to its original position while still retaining the previously mentioned AGC modification. It was recognized that this combination might cause scan frequency doubling at close ranges due to the saturation characteristic of the input TWT, but it was felt that the improvement in AGC performance was a more important factor.

A flight test of this combination was made on December 17. The results of this test were very similar to the results of the December 9 tests. Apparently the AGC modification caused little change in the performance of the Model 504; however, it was decided to leave the modification in since it still appeared theoretically desirable.

#### High Altitude Debugging

During the latter part of December the Model 504 was brought back to Palo Alto for testing in the high altitude chamber. No trouble was experienced down

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to a pressure of 10 in. of Hg; however, below this, arcing occurred in the high voltage section. Corona Dope was used to paint various terminals and several leads were insulated. This resulted, finally, in being able to operate down to pressures of 6 in. of Hg which <sup>gave</sup> ~~gives~~ a safety factor of 1.5 at 4.5 psi.

Previously it was noted that the output TWT was not being completely cut off by the modulating signal applied to its grid. The on-to-off signal ratio was about 28 db. Since this would limit the J/s ratio to less than 28 db, it was felt that the grid drive should be increased to cut off the TWT completely. This modification was made following the high altitude debugging.

It was also noted at this time that the phase of the Model 504 return was still lagging slightly at 75 cps. Additional phase lead was applied to optimize the phase return.

#### Active Testing - Part 3

On January 9, 1959, another flight was arranged against the F3H at Point Mugu. During this test the pulse detection circuitry was jumpered so that the output TWT was on whenever the Enable (high voltage) switch was on. The purpose of this test was to determine if the Model 504 would act as a beacon if it were on all the time and to determine if in this mode the Model 504 would prevent initial lock-on. It

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was felt that the inverse gain circuits would hinder the beacon effect since they would turn the output TWT off as the search beam swept past the target.

A total of eight runs were made during this test. The 1st and 5th runs were calibration runs and indicated that the radar was operating normally. The 2nd and 8th runs were made with the radar in the search mode during the entire run, and the Model 504 Enable switch cycled every 15 seconds. The F3H pilot reported that the target increased in width when the Model 504 was on so that a considerable beacon action was taking place. Apparently the Model 504 was off during the center of the target spot but was on at the front and tail end so that the apparent size of the target was increased.

The remaining four runs were normal attack runs with the Model 504 on all of the time. During each of these runs the aim dot on the radar scope exhibited large excursions following in general a slow clockwise path around the scope, and it was impossible for the F3H pilot to center the aim dot even at a range of one mile. Only once did the F3H make a simulated firing and even then the F3H pilot indicated that the probability of a hit was very low.

Contrary to previous runs the radar did not lose lock at any range. A possible explanation for this is that the radar receiver sensitivity had been

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improved in the interim between the December 17 and January 9 tests. The Mugu personnel indicated that the receiver had been worked on during that period.

To the best of our knowledge a radar set loses lock when the return signal is too weak to maintain the range tracking function. This can occur either at large ranges or at large target offsets. The Model 504 attempts to break lock by causing large target offsets. However, the maximum offset that can occur is one which places the target at the first large side lobe since at this point the phase of the tracking system reverses and the inverse gain system then aids tracking instead of opposing it. The radar tracking system is then in a sort of equilibrium with an error magnitude which places the target near the first large side lobe and an error direction which rotates depending on the exact phase of the Model 504 return. If the Model 504 return were exactly  $180^{\circ}$  out of phase, the error direction would not rotate, while an increasing phase error would give an increasing rate of rotation. In order for the pilot to attempt to follow the aim dot, it is necessary that it not move too rapidly. Otherwise, the pilot merely averages the position of the aim dot and can fly a fairly accurate path to the target.

If the radar sensitivity is such that it can maintain range tracking even with the target at the first large side lobe, then lock will not be broken. If,

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on the other hand, the combination of range and target error combine to present too weak a return to the radar, then lock will be broken. Anything which increases the noise seen by the radar, such as ground clutter, will increase the probability of lock break.

The test on January 9 indicated that the Model 504 was effective at much closer ranges than previously. Several possibilities exist for explaining this:

- 1) The additional phase correction may have made significant difference in the Model 504 performance.
- 2) The radar output power may not have been as great as on previous tests.

Neither explanation, however, appears completely satisfactory.

In general, the bypassing of the pulse detection circuitry was not satisfactory since the Model 504 did act as a beacon and since it had little effect on the ability of the radar to lock <sup>on</sup> ~~out~~ the target. The Model 504 was, therefore, restored to its original mode of operation.

#### Operational Testing

At this time it was felt that testing at Point Mugu should be terminated and that operational testing at Edwards Air Force Base ~~be~~ be initiated

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Leonard D. Leader

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**SECRET****PROJECT 42 - HISTORICAL RECORD****ADDENDUM**

On page 11 of the historical record, two possible explanations for the increased effectiveness of the 504 at close ranges were listed. A third possibility exists. Prior to the January 9th test, the modulating signal fed to the grid of the output traveling wave tube was increased in amplitude so that the on-to-off signal ratio was increased from about 28 db to essentially infinity. This change may have increased the target offset at far ranges sufficiently that the 504 did not become power limited as the range decreased.

4/7/59

*Leonard D. Seader*

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